(NASA-CR-156573) COMPARISON OF ACOUSTIC AND VIBRATION ENVIRONMENT OF APOLLO SPACECRAFT (Bellcomm, Inc.) 12 p

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SUBJECT: Comparison of Acoustic and Vibration Environment of Apollo Spacecraft as given by NAA and MSFC -- Case 201

DATE: November 4, 1964

FROM: J. L. Peterson
J. J. Schoch

SUMMARY

A brief comparison between NAA and MSFC vibration and acoustic data is given. It is shown that the NAA estimates are lower than the MSFC estimates for both the acoustic and vibration environment in the adapter-instrument unit region. A fairly good correspondence may be found between the NAA and MSFC data for the C.M. An explanation of the terms and definitions required to understand the graphs is given in the Appendix.

BELLCOMM, INC.

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MEMORANDUM FOR FILE

INTRODUCTION

In gathering information for use in writing a section on induced environment for the Project Spacecraft Requirement Specification, it was found that MSC has at the present no document that covers induced environment. There are specifications by the prime contractors, NAA and Grumann. An attempt is made here to compare NAA's data with MSFC's test requirements in the fields of acoustics and random vibrations on the exterior side of the spacecraft.

ACOUSTICS

MSFC provides in Reference 1 acoustic data for the complete launch vehicle which is, for this purpose, divided in different zones. Of particular interest for the comparison at hand is the zone defined as Payload (Page 300) and the zone defined as Instrument Unit (Page 299). North American Aviation shows in Reference 2 (Pages 46-47) acoustic data for various parts of the CM, the SM, and the Adapter. Comparison between the two documents is possible in two zones. The zone called "Instrument Unit" by MSFC should compare with NAA's "Adapter" and MSFC general zone termed "Payload" should be a general envelope of NAA detailed data for various locations along the CSM. Figure No. 1 compares the sound pressure levels in the adapter-instrument unit region. MSFC's data was given in Reference 1 in tabular form in function of one third octave band geometric mean frequencies. These data were transformed into octave band frequencies in order to make them comparable to the curves given in Reference 2. Figure 1 shows that NAA's values for sound pressure level (SPL) are slightly higher at frequencies below 180 CPS but fall far below MSFC values at the higher frequencies. Overall SPL as estimated by NAA is about 10 dB lower than MSFC's.

Figure No. 2 compares MSFC's overall spacecraft curve with various NAA curves. Only NAA curves which either came close or intersected MSFC's envelope curve were selected. It may be noted that very few of the curves intersect the MSFC envelope and that NAA's overall sound pressure level is at least 5 dB lower than the MSFC overall sound pressure level.

[redacted]

RANDOM VIBRATION

The only possible comparison between Reference 1 and 2 is in the SM-Adapter-Instrument Unit area. The applicable values are plotted on Figure 3 as acceleration spectral density in G^2/CPS versus frequency in CPS. The curve shows that generally speaking the NAA curve is lower than the MSFC curve.

Reference 3 contains a comparison between MSFC and MSC vibration data for the CM. The source of the MSC data presented in Reference 3 is now known. In observing this comparison for random vibration one gets the impression that the values given for MSC are slightly higher than the ones given by MSFC in the rear of the command module but lower than the MSFC data for the front of the CM. This is due to the fact that the MSC data given in Reference 3 are identical for all regions of the CM. Newest data from NAA, Reference 2 shows differences between different sections of the CM and according to those figures the MSFC data are consistently lower than the NAA data. Figure No. 4 compares the MSFC data from Reference 3 with the newest NAA figures in the front and rear of the CM. The figure also shows that overall CM vibration levels from MSC (Reference 3) correspond to the NAA's data for aft heat shield in Reference 2.

CONCLUSIONS

The NAA specifications for both the acoustic and the vibration environment in the adapter-instrument unit region are lower than the values established by MSFC. Fairly good correspondence is found in the CM area.

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Attachment
Appendix

Distribution
See attached page

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APPENDIX

For the benefit of the reader not used to the terminology used in this memorandum, a brief explanation of the common terms follows:

ACOUSTICS

Sound Intensity (I) is the acoustic power hitting a unit of surface. It is usually expressed in Watts/CM^2.

Sound Intensity Level is defined as

$$SIL = 10 \ Log_{10} \left(\frac{I}{Io}\right).$$

It is expressed in decibels (dB). Io is equal to the arbitrarily selected sound intensity reference which is usually the lower audible limit, 10^{-16} Watt/CM^2. When a sound intensity level in dB is given the reference sound intensity, Io, should always be defined.

Sound Pressure is related to sound intensity by

$$I = \frac{P^2}{\rho c}$$

where

ρ is density

c velocity of sound

Sound Pressure Level may be obtained by substituting the above relation in the definition for sound intensity level or

$$SPL = 10 \ Log_{10} \left(\frac{\frac{P^2}{\rho c}}{\frac{P^2}{\rho c_o}}\right) = 10 \ Log_{10} \left(\frac{P^2}{{P_o}^2}\right) = 20 \ Log_{10} \left(\frac{P}{P_o}\right)$$

This is correct under the assumption that the velocity of sound and the density are constant.

The reference sound pressure has to be provided to make this expression meaningful. It is usually P_o = 0.0002 Dynes/CM^2 or microbar (which is also equivalent to 2×10^{-5} NEWTON/M^2 (N/M^2).

Sound pressure level is also given in dB. Only for one specific temperature will the SIL and the SPL have the same numerical value in dB.

Both SIL and SPL are measured for a certain frequency band. Consequently, in comparing different data it may be necessary to convert the data to the same band width. Given for instance the sound pressure P_1 and P_2 for the bands 1 and 2, then the SPL for the combined band consisting of both bands 1 and 2 is given by

$$SPL_{1-2} = \text{Log}_{10} \left(\frac{P_1^{\ 2} + P_2^{\ 2}}{P_o^{\ 2}} \right)$$

Overall Sound Pressure Level is the SPL corresponding to the whole frequency band as given by

$$SPL_{overall} = 10 \ \text{Log}_{10} \left[\frac{\sum_{i=1}^{n} P_i^2}{P_o^2} \right]$$

RANDOM VIBRATION

Vibrations are measured in terms of G. This means that a G value of 2 corresponds to twice the acceleration of gravity.

Mean Square Acceleration. Since the vibration has no definite peak value its mean square acceleration is used. It is defined as:

$$\overline{A}^2 = \lim_{\tau \to \infty} \frac{1}{\tau} \int_0^{\tau} a^2 (t) \, dt \qquad (G^2)$$

If a (t) were periodic it would be sufficient to integrate over one period.

<u>Acceleration Power Spectral Density</u>. The vibration is often described in spectral terms. This is done by dividing the frequency range into smaller frequency bands, measuring the mean square acceleration in each band and dividing it by its bandwidth. The function obtained by allowing the bandwidth Δf to approach zero is called acceleration power spectral density and the whole function plotted against frequency is called the power spectrum. Thus, the acceleration power spectral density

$$APSD = \lim_{\Delta f \to 0} \left(\frac{\bar{A}^2 \; (f, \Delta f)}{\Delta f} \right)$$

where Δf expresses the frequency bandwidth and $\bar{A}^2$ the mean square acceleration at a frequency f and a bandwidth Δf.

<u>Calculations of Slopes in dB/Octave</u>. In a graph of power spectral density in G^2/CPS vs frequency in CPS on log log paper the slopes of straight lines are given in dB/octave. These slopes may be computed easily remembering that

$$dB = 10 \; \mathrm{Log}_{10} \left(\frac{G^2/CPS_2}{G^2/CPS_1} \right)$$

and

$$OCT = 3.32 \; \mathrm{Log}_{10} \left(\frac{f_2}{f_1} \right)$$

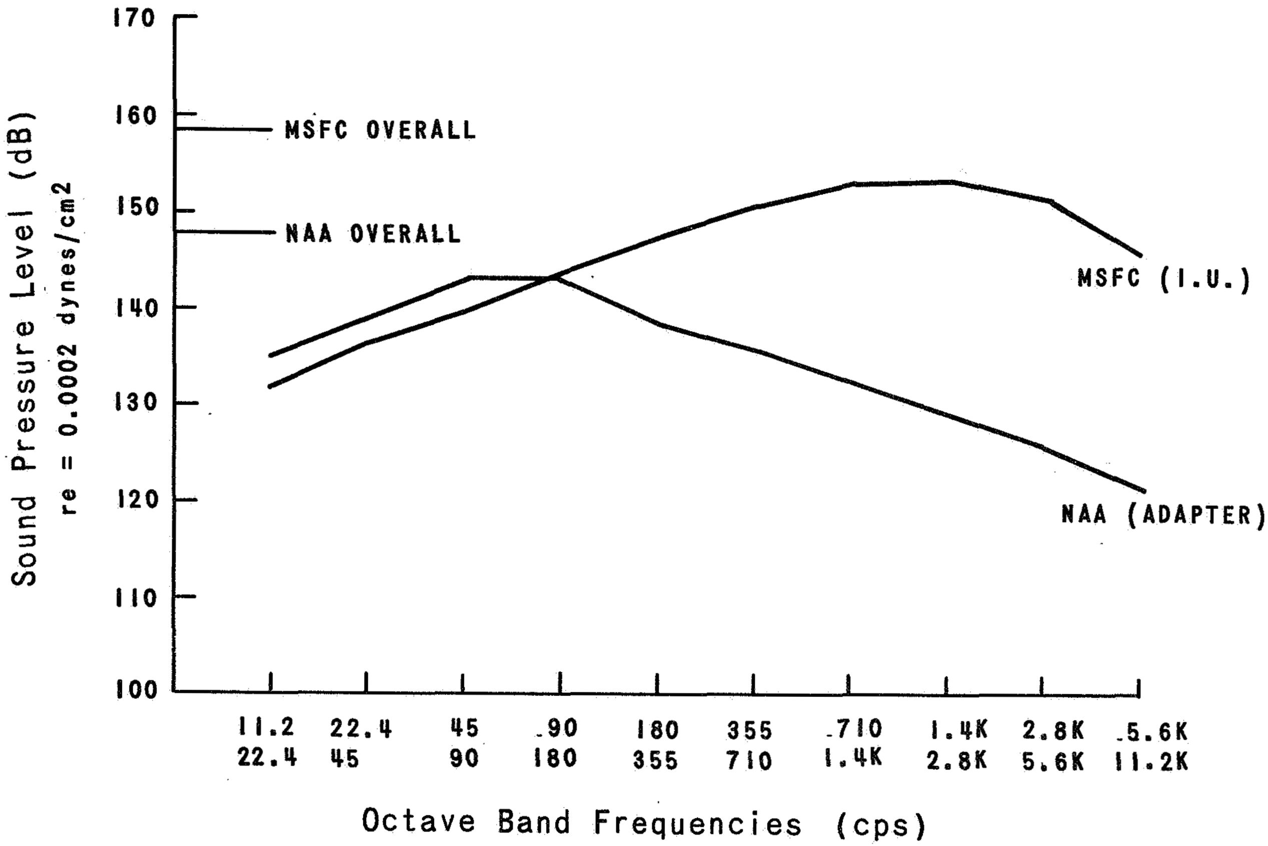

FIGURE I COMPARISON OF SOUND PRESSURE LEVEL IN THE ADAPTER - INSTRUMENT UNIT AREA

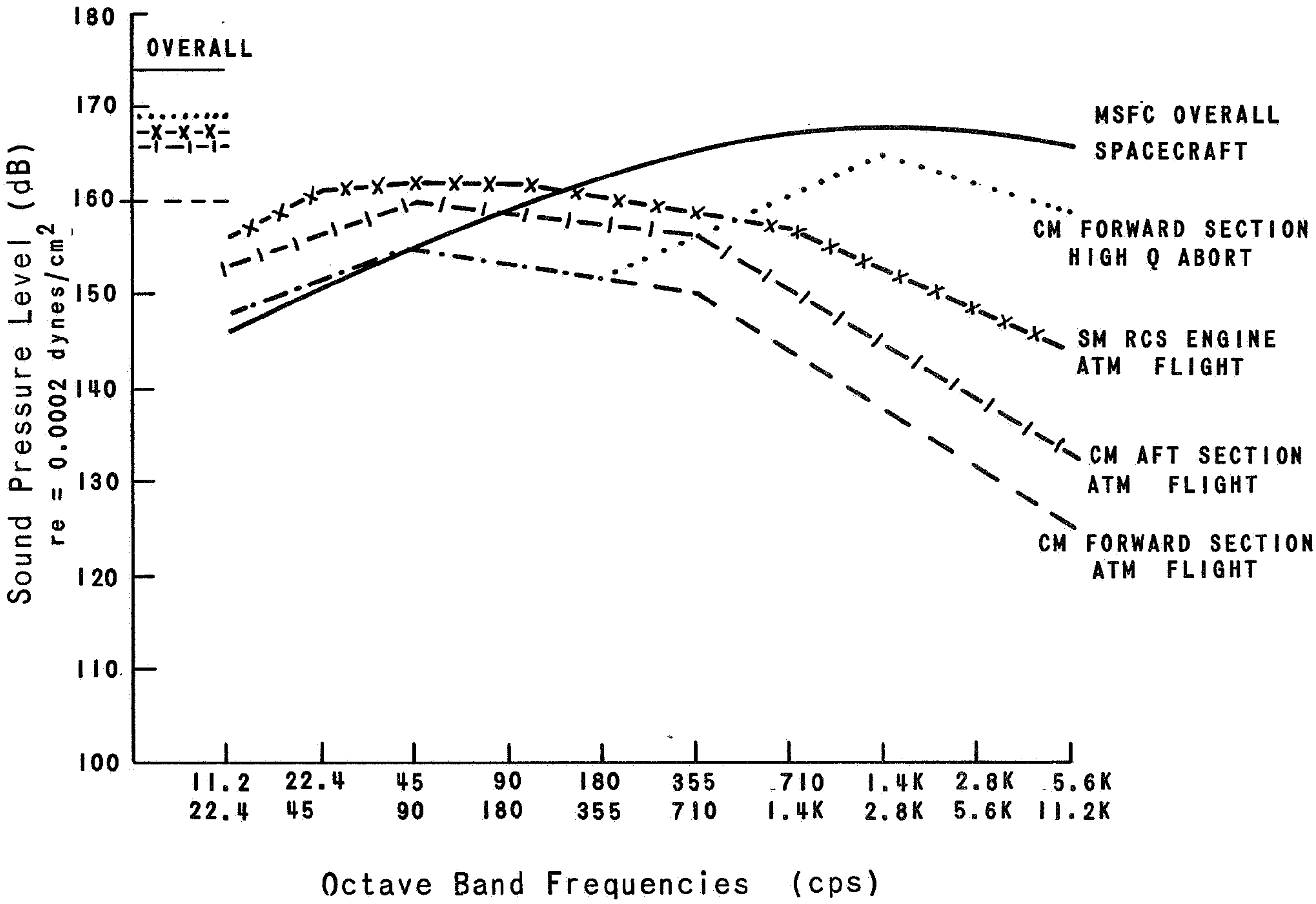

FIGURE 2 COMPARISON OF SOUND PRESSURE LEVEL. MSFC CURVE FOR PAYLOAD AS CCMPARED TO CURVES BY NAA FOR VARIOUS CSM COMPONENTS

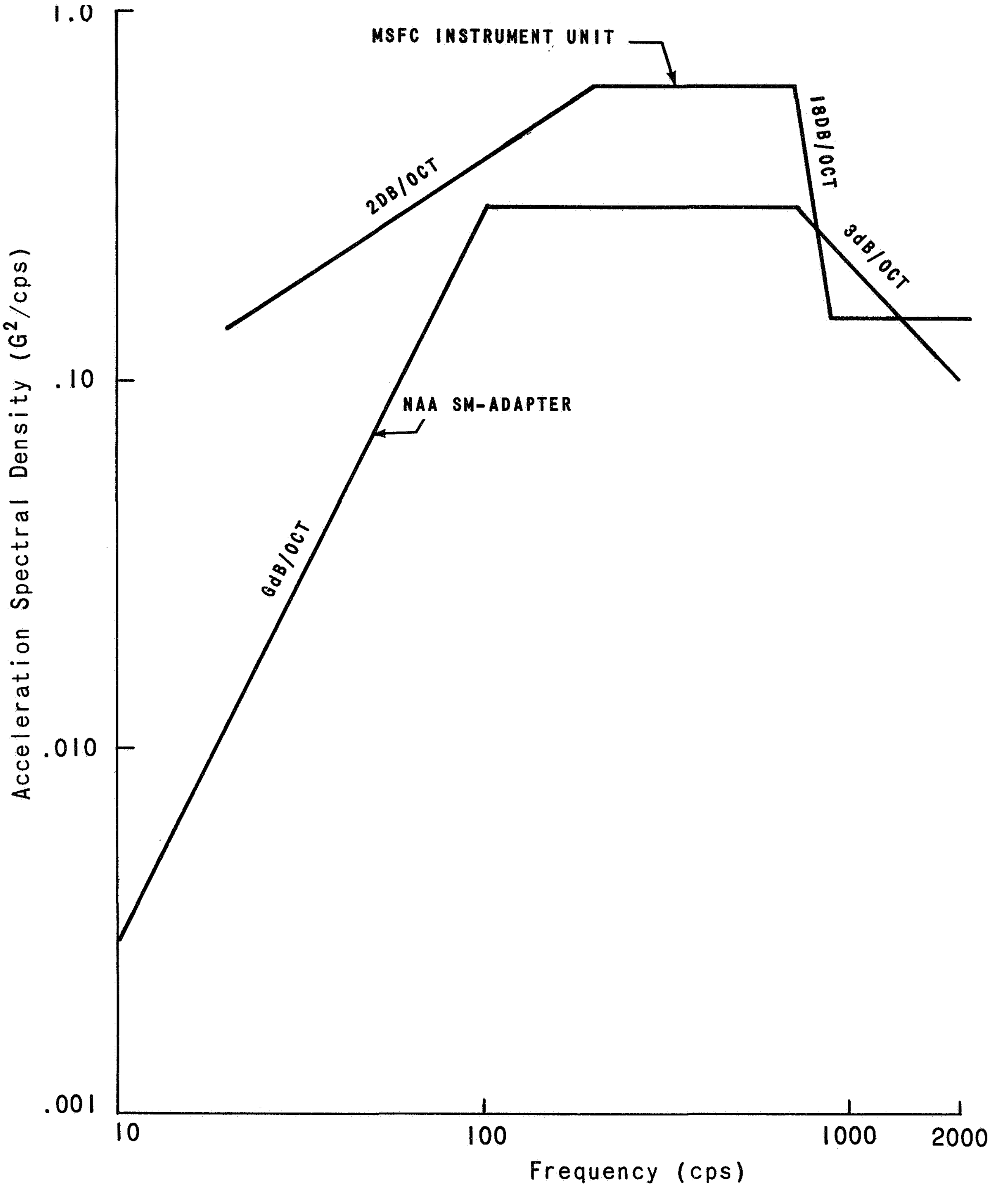

FIGURE 3 COMPARISON OF RANDOM VIBRATION

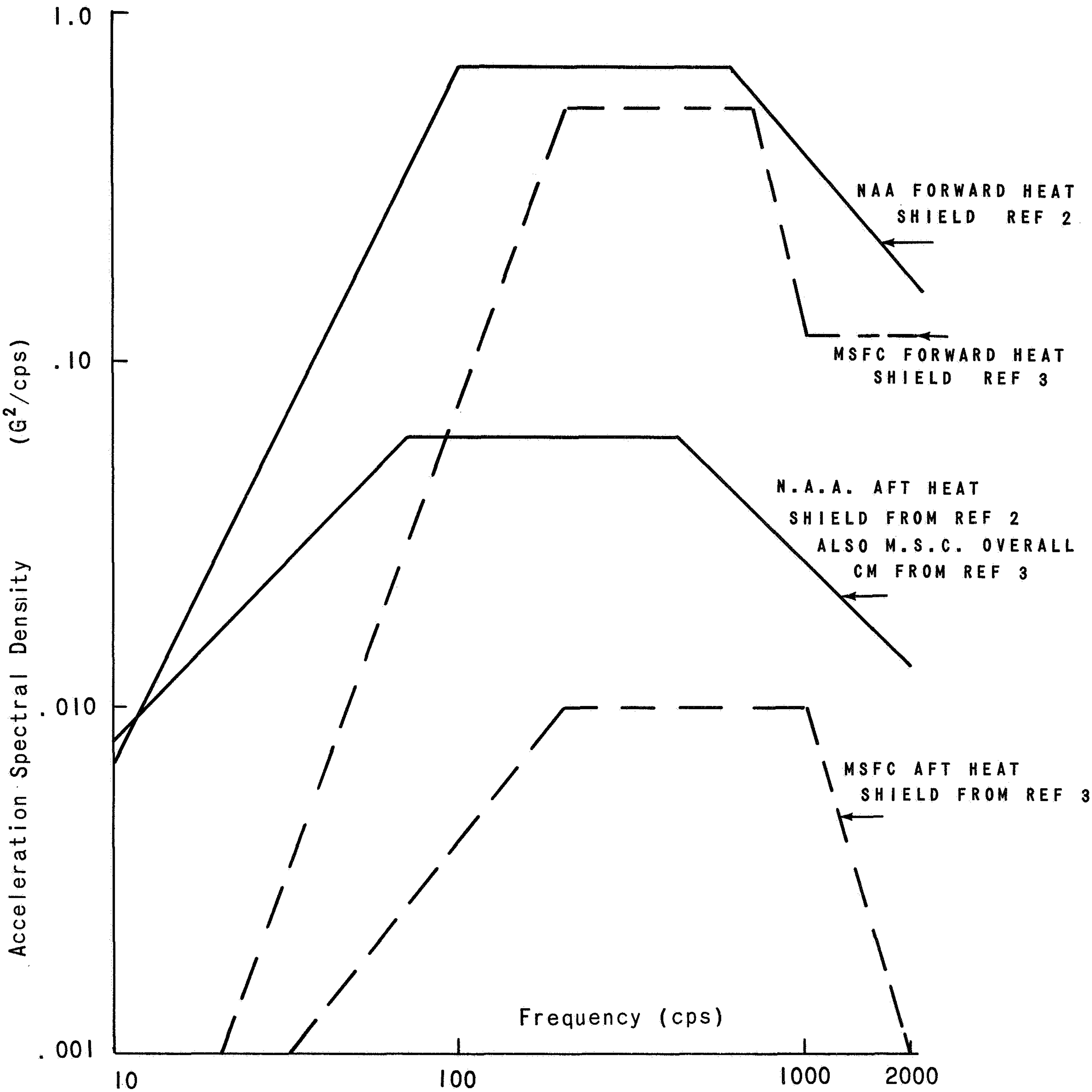

FIGURE 4 COMPARISON OF CM VIBRATION DATA

REFERENCES

1. IN-P & VE-S-63-2 Revised September 11, 1964
   Internal Note, Preliminary Vibration, Acoustic, and Shock Specifications for Components on Saturn V Vehicle, by Vibration and Acoustics Branch (For internal use only).

2. North American Aviation, Inc. SISD MC 999-0051 dated July 31, 1964, Apollo Environmental Design and Test Requirements.

3. R-P&VE-SVR-64-102 July 30, 1964
   Apollo Spacecraft Vibration Environment.

4. Charles T. Morrow; Shock and Vibration Engineering, Volume 1; John Wiley & Sons (Reference of general interest).